LENS BARREL

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application relates to the following U.S. Patent Applications, all filed concurrently herewith on September 24, 2001, and all of which are expressly incorporated herein by reference in their entireties: "ZOOM LENS MECHANISM" having attorney docket No. P21180, "ZOOM LENS MECHANISM" having attorney docket No. P21181, "ECCENTRICITY-PREVENTION MECHANISM FOR A PAIR OF LENS-SUPPORTING RINGS" having attorney docket No. P21182, "REDUCTION GEAR MECHANISM" attorney docket No. P21183, "RING MEMBER SHIFT MECHANISM AND LENS GROUP SHIFT MECHANISM" having attorney docket No. P21184, "LENS BARREL" having attorney docket No. P21185, "LENS BARREL" having attorney docket No. P21186, "LENS BARREL" having attorney docket No. P21187, "ZOOM LENS BARREL" having attorney docket No. P21190, and "LENS BARREL" having attorney docket No. P21192, each naming as inventors Hiroshi NOMURA et al.; and "LENS DRIVE CONTROL APPARATUS FOR ZOOM LENS SYSTEM HAVING A SWITCHING LENS GROUP" having attorney docket No. P21189 and naming as inventor Norio NUMAKO.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a lens barrels and, more particularly, relates to a structure for assembling/disassembling a lens barrel having a lens group guided in an optical axis direction of the lens group.

2. Description of the Related Art

It is desired that lens barrels have a construction that can be readily disassembled for the ease of replacement of the photographing lens group.

For example, the assignee of the present application has proposed a zoom lens system that achieves high zoom ratio while maintaining the advantage of constructing a smaller lens systems (U.S. Patent Application No.09/534,307, Japanese Patent Application No. Hei 11-79572). This zoom lens system has following characteristics: it includes a plurality of movable lens groups for varying the focal length; at least one of the lens groups is a switching lens group which includes two sub-lens groups, one of the sub-lens groups being a movable sub-lens group that can be selectively positioned at either one movement extremities in the optical axis direction with respect to the other sub-lens group; the movable sub-lens group of the switching

lens group is positioned at an extremity of a short-focal-length zooming range, from the short focal length extremity to an intermediate focal length, and at the opposite extremity of a long-focal-length zooming range, from the intermediate focal length to a long focal length extremity; and zoom paths of the switching lens group and the other lens groups are discontinuous at the intermediate focal length and are defined to focus on a predetermined image plane corresponding to the position of the movable sub-lens group.

It is especially required that the switching lens group unit, including the lens guide mechanism (linear guide mechanism), can be readily assembled or disassembled in the mechanical construction of the lens barrel used in such a zoom lens system since guiding each sub-lens group of the switching lens group, which provides a single lens group, requires an individual guide mechanism.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to facilitate assembly/disassembly of a lens barrel having a lens group which is guided in the optical axis direction of the lens group.

In order to achieve the above-mentioned object, A lens barrel including a lens frame for supporting a photographing lens group, the lens frame including a guide bore which extends in a direction parallel to the optical axis of the photographing lens group; a support barrel, wherein the lens frame can be inserted into and removed from a front opening of the support barrel; a rod receiving portion formed inside the support barrel at the rear of the front opening in the optical axis direction; a bracket detachably attached to a front end of the support barrel to prevent the lens frame from falling out of the front of the support barrel; and a guide rod provided on the bracket for guiding the lens frame to move relative to the support barrel in the optical axis direction, the guide rod being placed through the guide bores and the end of the guide rods engaging with the rod receiving portion when the bracket is attached to the support barrel. The lens group frame can be taken out of the support barrel through the front opening when the bracket having the guide rod is removed from the support barrel.

Preferably, the lens barrel includes a plurality of the guide bores, a plurality of the rod receiving portions, and a plurality of the guide rods.

Preferably, a biasing spring is provided between the bracket and the lens group frame for biasing the lens group frame rearward in the optical axis direction.

Preferably, the guide rod is removable with respect to the bracket, and is secured to the bracket before the bracket is attached to the support barrel.

In an embodiment, the lens barrel further includes a first sub-lens group provided on the object side and a second sub-lens group provided on the image side with respect to the first sub-lens group, the first and second sub-lens groups functioning optically in a mutually close position and in a mutually distant position in the optical axis direction. The lens frame, which is guided by the guide rod, constitutes a first sub-lens group frame which supports the first sub-lens group. The support barrel further supports a second sub-lens group frame, which supports the second sub-lens group, wherein the second lens group frame can be inserted into and taken out of the support barrel through the front opening. The first lens group frame and the second lens group frame can be taken out of the support barrel from the front opening in that order, upon removal of the bracket from the support barrel.

Preferably, the lens barrel further includes an

actuator ring rotatably supported by the support barrel in the rear of the second sub-lens group frame so as not to move in the optical axis direction, the actuator ring being rotated so as to drive the first sub-lens group frame and the second sub-lens group frame with respect to the support barrel. The second sub-lens group frame is prevented from moving rearward due to the second sub-lens group frame being in contact with the actuator ring, and the first sub-lens group frame is prevented from moving rearward due to the first sub-lens group frame being in contact with the second sub-lens group frame.

In an embodiment, the second sub-lens group frame is supported in the support barrel so that the second sub-lens group frame can rotate in one and the other direction over a predetermined angle, and the second sub-lens group frame is guided to move in the optical axis direction at each rotational movement extremity thereof. The rotation of the actuator ring selectively causes the second sub-lens group frame to rotate and to move in the optical axis direction. The rotation of the second sub-lens group frame causes the first sub-lens group frame and the second sub-lens group frame to move to the mutually close position and to the mutually distant position. The movement of the second

sub-lens group frame in the optical axis direction causes the first sub-lens group frame to integrally move with the second sub-lens group frame in the optical axis direction.

In an embodiment, the first sub-lens group and the second sub-lens group are one of a plurality of variable lens groups of a zoom lens system, wherein the relative position of the first and second sub-lens group frames is switched to the mutually close position and the mutually distant position in the zooming operation. The first and second sub-lens groups serve as a focusing lens group when the first and second sub-lens group frames are integrally moved in the optical axis direction in the mutually close position and in the mutually distant position.

In an embodiment, a shutter member which can be selectively opened and closed is provided on the support barrel in the rear of the lens frame.

The present disclosure relates to subject matter contained in Japanese Patent Application No. 2000-289387 (filed on September 22, 2000) which is expressly incorporated herein in its entirety.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic drawing of a first embodiment

of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present invention is applied.

Figure 2 is a schematic drawing of a second embodiment of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present invention is applied.

Figure 3 is a schematic drawing of a third embodiment of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present invention is applied.

Figure 4 is a schematic drawing of a fourth embodiment of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present invention is applied.

Figure 5 is a schematic drawing of a fifth embodiment of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present invention is applied.

Figure 6 is a schematic drawing of a sixth embodiment of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present invention is applied.

Figure 7 is a schematic drawing of a seventh embodiment of a zoom lens system having switching lens groups and the fundamental zoom path thereof, to which the present invention is applied.

Figure 8 shows one example of stopping positions of the lens groups when a photographic operation is carried out, to which the present invention is applied.

Figure 9A shows an example of the stopping positions of Figure 8 and an example of an actual zoom path of the lens groups, to which the present invention is applied.

Figures 9B and 9C depict an additional schematic view of the concepts shown in Figs. 8 and 9

Figure 10 is a cross-sectional view showing an embodiment of a zoom lens barrel which includes the zoom lens systems having switching lens groups shown in Figures 1, 8 and 9.

Figure 11 is a developed view of an inner surface of a cam ring of the zoom lens barrel of Figure 10 showing an exemplary arrangement of cam grooves.

Figure 12 is an exploded perspective view showing components of a switching lens group frame of the zoom lens barrel.

Figure 13 is an exploded perspective view showing some

of the components of the switching lens group frame of the zoom lens barrel.

Figure 14 is a perspective view showing a different assembly of some of the components of the switching lens group frame of the zoom lens barrel.

Figure 15 is a cross-sectional view of an upper half of the switching lens group in which a first sub-lens group and a second sub-lens group are in a mutually distant position at the wide-angle extremity.

Figure 16 is a cross-sectional view of an upper half of the switching lens group in which the first sub-lens group and the second sub-lens group are in a mutually close position at the telephoto extremity.

Figure 17A is an exploded view in which components are exploded in the optical axis direction, wherein the first sub-lens group and the second sub-lens group are in the mutually distant position at the wide-angle side and are focused on an object at infinity.

Figure 17B is a developed view showing the components of Figure 17A in actual engagement.

Figure 18A is an exploded view in which components are exploded in the optical axis direction, wherein the first sub-lens group and the second sub-lens group are in the

mutually distant position at the wide-angle side and are focused on an object at a minimum distance.

Figure 18B is a developed view showing the components of Figure 18A in actual engagement.

Figure 19A is an exploded view in which components are exploded in the optical axis direction, wherein the first sub-lens group and the second sub-lens group are in the mutually close position at the telephoto side and are focused on an object at infinity.

Figure 19B is a developed view showing the components of Figure 19A in actual engagement.

Figure 20A is an exploded view in which components are exploded in the optical axis direction, wherein the first sub-lens group and the second sub-lens group are in the mutually close position at the telephoto side and are focused on an object at a minimum distance.

Figure 20B is a developed view showing the components of Figure 20A in actual engagement.

Figure 21 is an exploded view illustrating how the mutually close position of the first sub-lens group and the second sub-lens group on the telephoto side switches to/from the mutually distant position on the wide-angle side via the rotation of an actuator ring.

Figure 22 illustrates how focusing is carried out by the actuator ring.

Figure 23 is an enlarged expanded view showing a face cam of a first sub-lens group frame.

Figure 24 is an enlarged developed view showing the relationship of the first sub-lens group frame, the second sub-lens group frame, and the actuator ring with respect to a front shutter retaining ring.

Figure 25 is a front view showing the relationship between the first sub-lens group frame and the front shutter retaining ring when viewed in a direction of the arrows indicated by a line XXV-XXV in Figure 14.

Figure 26 is a partially enlarged view showing an encircled portion indicated by XXVI in Figure 25.

Figure 27 is a front view showing the relationship between the second sub-lens group frame and the front shutter retaining ring when viewed in a direction of the arrows indicated by the line XXVII-XXVII in Figure 14.

Figure 28 is a partially enlarged view showing an encircled part XXVIII in Figure 27.

Figure 29 is a front view showing an arrangement of reduction gears of a driving system of the actuator ring, the reduction gears being retained between the front shutter

retaining ring and the gear holding ring.

Figure 30 is a developed plan view of Figure 29.

Figure 31 is a block diagram showing a control system of the zoom lens barrel shown in Figure 10.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the embodiment described below, the present invention is applied to a lens barrel. This lens barrel is suitable for use with a zoom lens system proposed by the assignee of the present application in the U.S. Patent Application No.09/534,307. U.S. Patent Application No. 09/534,307 is expressly incorporated herein by reference in its entirety.

First, embodiments of a zoom lens system with a switching lens group proposed in the U.S. Patent Application No.09/534,307 will be herein described.

Figure 1 shows the first embodiment of the zoom lens system. The zoom lens system includes a positive first variable lens group 10, and a negative second variable lens group 20, in that order from the object side. The first variable lens group 10 includes a negative first lens group L1 (first sub-lens group S1) and a positive second lens group L2 (second sub-lens group S2), in that order from the object

side. The second variable lens group 20 includes a negative third lens group L3. The second sub-lens group S2 of the first variable lens group 10 is fixed to a first lens group frame 11. The first sub-lens group S1 is mounted on a movable sub-lens group frame 12. The movable sub-lens group frame 12 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 13 which is formed on the first lens group frame 11. The first sub-lens group S1 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the front end of the guide groove 13, or the image-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the rear end of the guide groove 13. The third lens group L3 is fixed to a second lens group frame 21. A diaphragm D is arranged to move together with the first variable lens group 10 (first lens group frame 11). Throughout Figures 1 through 9, IM indicates an image plane (film surface, and so forth) which is at a predetermined position.

In the zoom paths according to the first embodiment, the first variable lens group 10 (first lens group frame 11), the second variable lens group 20 (second lens group frame

21), and the first sub-lens group S1 (movable sub-lens group frame 12) move in the following manner:

[A] In a short-focal-length zooming range Zw from the short focal length extremity fw to an intermediate focal length fm, the first sub-lens group S1 and the second sub-lens group S2 maintain a distance d1 therebetween (first separation space/wide space); and the first variable lens group 10 (first lens group frame 11) and the second variable lens group 20 (second lens group frame 21) move towards the object side while mutually changing the distance therebetween.

[B] At the intermediate focal length fm, the first variable lens group 10 and the second variable lens group 20 move towards the image side at the long focal-length extremity of the short-focal-length zooming range Zw; and the first sub-lens group S1 moves to the image-side movement extremity of the guide groove 13, wherein the first sub-lens group S1 moves toward the second sub-lens group S2 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space) d2.

[C] In a long-focal-length zooming range Zt from the intermediate focal length fm to the long focal length extremity ft, the first sub-lens group S1 maintains the

shorter distance (second separation space/narrow space) d2 with respect to the second sub-lens group S2; and the first variable lens group 10 and the second variable lens group 20 move towards the object, based on the positions thereof which are determined at the intermediate focal length fm, after the first through third lens groups L1 through L3 have been moved towards the image side, while changing the distance therebetween.

The zoom paths for the first variable lens group 10 and the second variable lens group 20 are simply depicted as straight lines in Figure 1. It should be noted, however, that the actual zoom paths are not necessarily straight lines.

Focusing is performed by integrally moving, in the optical axis direction, the first sub-lens group S1 and the second sub-lens group S2, i.e., the first variable lens group 10 (first lens group frame 11) regardless of the zooming range.

Figure 2 shows the second embodiment of the zoom lens system. The zoom lens system includes a positive first variable lens group 10, a positive second variable lens group 20, and a negative third variable lens group 30, in that order from the object side. The first variable lens

group 10 includes a positive first lens group L1. The second variable lens group 20 includes a negative second lens group L2 (first sub-lens group S1) and a positive third lens group L3 (second sub-lens group S2), in that order from the object side. The third variable lens group 30 includes a negative fourth lens group L4. The first lens group L1 is fixed to a first lens group frame 11. The second sub-lens group S2 of the second variable lens group 20 is fixed to a second lens group frame 21. The first sub-lens group S1 is mounted on a movable sub-lens group frame 22. The movable sub-lens group frame 22 is arranged to move, in the optical axis direction, by a predetermined distance, along a guide groove 23 which is formed on the second lens group frame 21. The first sub-lens group S1 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the front end of the guide groove 23, or the image-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the rear end of the guide groove 23. The fourth lens group L4 is fixed to a third lens group frame 31. A diaphragm D is arranged to move together with the second variable lens group 20 (second lens group frame 21).

In the zoom paths according to the second embodiment,

the first variable lens group 10 (first lens group frame 11), the second variable lens group 20 (second lens group frame 21), the third variable lens group 30 (third lens group frame 31), and the first sub-lens group S1 (movable sub-lens group frame 22) move in the following manner:

[A] In a short-focal-length zooming range Zw from the short focal length extremity fw to an intermediate focal length fm, the first sub-lens group S1 and the second sub-lens group S2 maintain a distance d1 (first separation space/wide space); and the first variable lens group 10 (first lens group frame 11), the second variable lens group 20 (second lens group frame 21) and the third variable lens group 30 (third lens group frame 31) move towards the object side while mutually changing the distances therebetween.

[B] At the intermediate focal length fm, the first variable lens group 10, the second variable lens group 20 and the third variable lens group 30 are moved towards the image side at the long focal-length extremity of the short-focal-length zooming range Zw; and the first sub-lens group S1 moves to the image-side movement extremity of the guide groove 23, wherein the first sub-lens group S1 moves toward the second sub-lens group S2 so that the distance therebetween is determined by a shorter distance (second

separation space/narrow space) d2.

[C] In a long-focal-length zooming range Zt from the intermediate focal length fm to the long focal length extremity ft, the first sub-lens group S1 and the second sub-lens group S2 maintain the shorter distance d2; and the first variable lens group 10, the second variable lens group 20 and third variable lens group 30 move towards the object side based on the positions thereof which are determined at the intermediate focal length fm, after the first through fourth lens groups 1 through 4 have been moved towards the image side, while changing the distances therebetween.

The zoom paths for the first variable lens group 10, the second variable lens group 20 and the third variable lens group 30 are simply depicted as straight lines in Figure 2. It should be noted, however, that actual zoom paths are not necessarily straight lines.

Focusing is performed by integrally moving, in the optical axis direction, the first sub-lens group S1 and the second sub-lens group S2, i.e., the second variable lens group 20 (second lens group frame 21) regardless of the zooming range.

Likewise with the first embodiment, the zoom paths are discontinuous at the intermediate focal length fm; however,

a solution for continuously forming a correct image plane exists by appropriately determining the positions of the first lens group L1, the first sub-lens group S1 (second lens group L2) and the second sub-lens group S2 (third lens group L3) and the fourth lens group L4 respectively at the short focal length extremity fw, the intermediate focal length fm (discontinuous line) and the long focal length extremity ft. According to such a zoom path, a miniaturized zoom lens system having a high zoom ratio can be obtained.

Figure 3 shows the third embodiment of the zoom lens system with a switching lens system. In this embodiment, the first lens group L1 is constructed so as to have negative refractive power, which is the only difference compared with the second embodiment. Apart from this characteristic, the third embodiment is substantially the same as the second embodiment.

Figure 4 shows the fourth embodiment of the zoom lens system with a switching lens group. The zoom lens system includes a positive first variable lens group 10, and a negative second variable lens group 20, in that order from the object side. The first variable lens group 10 includes a negative first lens group L1 (first sub-lens group S1) and a positive second lens group L2 (second sub-lens group S2),

in that order from the object side. The second variable lens group 20 includes a positive third lens group L3 (third sub-lens group S3) and a negative fourth lens group L4 (fourth sub-lens group S4), in that order from the object side.

The second sub-lens group S2 of the first variable lens group 10 is fixed to a first lens group frame 11. The first sub-lens group S1 is mounted on a movable sub-lens group frame 12. The movable sub-lens group frame 12 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 13 which is formed on the first lens group frame 11. The first sub-lens group S1 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the front end of the guide groove 13, or the image-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the rear end of the guide groove 13. Similarly, the fourth sub-lens group S4 of the second variable lens group 20 is fixed to a second lens group frame 21. The third sub-lens group S3 is mounted on a movable sub-lens group frame 22. The movable sub-lens group frame 22 is arranged to move in the optical axis direction, by a predetermined distance, along

a guide groove 23 which is formed on the second lens group frame 21. The third sub-lens group S3 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the front end of the guide groove 23, or the image-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the rear end of the guide groove 23. A diaphragm D is arranged to move together with the first variable lens group 10 (first lens group frame 11).

In the zoom paths according to the fourth embodiment, the first variable lens group 10 (first lens group frame 11), the second variable lens group 20 (second lens group frame 21), the first sub-lens group S1, and the third sub lens group S3 move in the following manner:

[A] In a short-focal-length zooming range Zw from the short focal length extremity fw to an intermediate focal length fm, the first sub-lens group S1 and the second sub-lens group S2 maintain a distance d1 therebetween (first separation space/wide space), and the third sub-lens group S3 and the fourth sub-lens group S4 maintain a distance d3 therebetween (first separation space/wide space); and the first variable lens group 10 (first lens group frame 11) and the second variable lens group 20 (second lens group frame

21) move towards the object side while mutually changing the distance therebetween.

[B] At the intermediate focal length fm, the first variable lens group 10 and the second variable lens group 20 are moved towards the image side at the long focal-length extremity of the short-focal-length zooming range Zw; and the first sub-lens group S1 moves to the image-side movement extremity of the guide groove 13, wherein the first sub-lens group S1 moves toward the second sub-lens group S2 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space) d2, and also the third sub-lens group S3 moves toward the fourth sub-lens group S4 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space) d4.

[C] In a long-focal-length zooming range Zt from the intermediate focal length fm to the long focal length extremity ft, the first sub-lens group S1 and the second sub-lens group S2 maintain the shorter distance d2 therebetween, and the third sub-lens group S3 and the fourth sub-lens group S4 maintain the shorter distance d4 therebetween; and the first variable lens group 10 and the second variable lens group 20 move towards the object side

based on the positions thereof which are determined at the intermediate focal length fm, after the first through fourth lens groups L1 through L4 have been moved towards the image side, while changing the distance therebetween.

The zoom paths for the first variable lens group 10 and the second variable lens group 20 are simply depicted as straight lines in Figure 4. It should be noted, however, that the actual zoom paths are not necessarily straight lines.

Focusing is performed by integrally moving, in the optical axis direction, the first sub-lens group S1 and the second sub-lens group S2, i.e., the first variable lens group 10 (first lens group frame 11) regardless of the zooming range.

Similar to the first through third embodiments, in the fourth embodiment, the zoom paths are discontinuous at the intermediate focal length fm; however, a solution for continuously forming a correct image plane exists by appropriately determining the positions of the first sub-lens group S1 (first lens group L1), the second sub-lens group S2 (second lens group L2), the third sub-lens group S3 (third lens group L3), and the fourth sub-lens group S4 (fourth lens group L4), respectively, at the short focal

length extremity fw, the intermediate focal length fm (discontinuous line), and the long focal length extremity ft. According to such a zoom path, a miniaturized zoom lens system having a high zoom ratio can be obtained.

Figure 5 shows the fifth embodiment of the zoom lens system with a switching lens group. The zoom lens system includes a positive first variable lens group 10, and a negative second variable lens group 20, in that order from the object side. The first variable lens group 10 includes a negative first lens group L1 (first sub-lens group S1) and a positive second lens group L2 (second sub-lens group S2), in that order from the object side. The second variable lens group 20 includes a positive third lens group L3 (third sub-lens group S3) and a negative fourth lens group L4 (fourth sub-lens group S4), in that order from the object side.

The second sub-lens group S2 of the first variable lens group 10 is fixed to a first lens group frame 11. The first sub-lens group S1 is mounted on a movable sub-lens group frame 12. The movable sub-lens group frame 12 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 13 which is formed on the first lens group frame 11. The first sub-lens group S1 is

selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the front end of the guide groove 13, or the image-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the rear end of the guide groove 13. Similarly, the fourth sub-lens group S4 of the second variable lens group 20 is fixed to a second lens group frame 21. The third sub-lens group S3 is mounted on a movable sub-lens group frame 22. The movable sub-lens group frame 22 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 23 which is formed on the second lens group frame 21. The third sub-lens group S3 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the front end of the guide groove 23, or the image-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the rear end of the guide groove 23. A diaphragm D is arranged to move together with the first variable lens group 10 (first lens group frame 11).

In the zoom paths according to the fifth embodiment, the first variable lens group 10 (first lens group frame 11), the second variable lens group 20 (second lens group frame

21), the first sub-lens group S1, and the third sub lens group S3 move in the following manner:

[A] In a short-focal-length zooming range Zw from the short focal length extremity fw to a first intermediate focal length fm1, the first sub-lens group S1 and the second sub-lens group S2 maintain a distance d1 therebetween (first separation space/wide space), and the third sub-lens group S3 and the fourth sub-lens group S4 maintain a distance d3 therebetween (first separation space/wide space); and the first variable lens group 10 (first lens group frame 11) and the second variable lens group 20 (second lens group frame 21) move towards the object side while mutually changing the distance therebetween.

[B] At the first intermediate focal length fm1, the first variable lens group 10 and the second variable lens group 20 are moved towards the image side at the long focal-length extremity of the short-focal-length zooming range Zw; and the first sub-lens group S1 moves to the image-side movement extremity of the guide groove 13, wherein the first sub-lens group S1 moved toward the second sub-lens group S2 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space) d2.

[C] In an intermediate zooming range Zm from the first intermediate focal length fm1 to a second intermediate focal length fm2, the first sub-lens group S1 and the second sub-lens group S2 maintain the shorter distance d2, and the third sub-lens group S3 and the fourth sub-lens group S4 maintain the longer distance d3; and the first variable lens group 10 and the second variable lens group 20 move towards the object side based on the positions thereof which are determined at the first intermediate focal length fm1, after the first through fourth lens groups L1 through L4 have been moved towards the image side, while changing the distance therebetween.

[D] At the second intermediate focal length fm2, the first variable lens group 10 and the second variable lens group 20 are moved towards the image side at the long focal length extremity of the intermediate zooming range Zm; and the third sub-lens group S3 moves to the image-side movement extremity of the guide groove 23, wherein the third sub-lens group S3 moves toward the fourth sub-lens group S4 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space) d4.

[E] In a long-focal-length zooming range Zt from the second intermediate focal length fm2 to the long focal

length extremity ft, the first sub-lens group S1 and the second sub-lens group S2 maintain the shorter distance d2 therebetween, and the third sub-lens group S3 and the fourth sub-lens group S4 maintain the shorter distance d4 therebetween; and the first variable lens group 10 and the second variable lens group 20 move towards the object side based on the positions thereof which are determined at the second intermediate focal length fm2, after the first through fourth lens groups L1 through L4 have been moved towards the image side, while changing the distance therebetween.

The zoom paths for the first variable lens group 10 and the second variable lens group 20 are simply depicted as straight lines in Figure 5. It should be noted, however, that the actual zoom paths are not necessarily straight lines.

Focusing is performed by integrally moving, in the optical axis direction, the first sub-lens group S1 and the second sub-lens group S2, i.e., the first variable lens group 10 (first lens group frame 11) regardless of the zooming range.

Similar to the first through fourth embodiments, in the fifth embodiment, the zoom paths are discontinuous at

the first intermediate focal length fm1 and the second intermediate focal length fm2; however, a solution for continuously forming a correct image plane exists by appropriately determining the positions of the first sub-lens group S1 (first lens group L1), the second sub-lens group S2 (second lens group L2), the third sub-lens group S3 (third lens group L3) and the fourth sub-lens group S4 (fourth lens group L4), respectively, at the short focal length extremity fw, the first and second intermediate focal lengths fm1, fm2 (discontinuous line), and the long focal length extremity ft. According to such a zoom path, a miniaturized zoom lens system having a high zoom ratio can be obtained.

Figure 6 shows the sixth embodiment of the zoom lens system with a switching lens group. The zoom lens system includes a positive first variable lens group 10, and a negative second variable lens group 20, in that order from the object side. The first variable lens group 10 includes a negative first lens group L1 (first sub-lens group S1) and a positive second lens group L2 (second sub-lens group S2), in that order from the object side. The second variable lens group 20 includes a positive third lens group L3 (third sub-lens group S3) and a negative fourth lens group L4

(fourth sub-lens group S4), in that order from the object side.

The second sub-lens group S2 of the first variable lens group 10 is fixed to a first lens group frame 11. The first sub-lens group S1 is mounted on a movable sub-lens group frame 12. The movable sub-lens group frame 12 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 13 which is formed on the first lens group frame 11. The first sub-lens group S1 is selectively moved to either the object-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the front end of the guide groove 13, or the image-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the rear end of the guide groove 13. Similarly, the fourth sub-lens group S4 of the second variable lens group 20 is fixed to a second lens group frame 21. The third sub-lens group S3 is mounted on a movable sub-lens group frame 22. The movable sub-lens group frame 22 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 23 which is formed on the second lens group frame 21. The third sub-lens group S3 is selectively moved to either the object-side movement extremity at which the

movable sub-lens group frame 22 comes into contact with the front end of the guide groove 23, or the image-side movement extremity at which the movable sub-lens group frame 22 comes into contact with the rear end of the guide groove 23. A diaphragm D is arranged to move together with the first variable lens group 10 (first lens group frame 11).

In the zoom paths according to the sixth embodiment, the first variable lens group 10 (first lens group frame 11), the second variable lens group 20 (second lens group frame 21), the first sub-lens group S1, and the third sub lens group S3 move in following manner:

[A] In a short-focal-length zooming range Zw from the short focal length extremity fw to a first intermediate focal length fm1, the first sub-lens group S1 and the second sub-lens group S2 maintain a distance d1 therebetween (first separation space/wide space), and the third sub-lens group S3 and the fourth sub-lens group S4 maintain a distance d3 therebetween (first separation space/wide space); and the first variable lens group 10 (first lens group frame 11) and the second variable lens group 20 (second lens group frame 21) move towards the object side while mutually changing the distance therebetween.

[B] At the first intermediate focal length fm1, the

first variable lens group 10 and the second variable lens group 20 are moved towards the image side at the long focal length extremity of the short-focal-length zooming range Zw; and the third sub-lens group S3 moves to the image-side movement extremity of the guide groove 23, and wherein the third sub-lens group S3 moves toward the fourth sub-lens group S4 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space) d4.

[C] In an intermediate zooming range Zm from the first intermediate focal length fm1 to a second intermediate focal length fm2, the first sub-lens group S1 and the second sub-lens group S2 maintain the longer distance d1 therebetween, and the third sub-lens group S3 and the fourth sub-lens group S4 maintain the shorter distance d4 therebetween; and the first variable lens group 10 and the second variable lens group 20 move towards the object side based on the positions thereof which are determined at the first intermediate focal length fm1, after the first through fourth lens groups L1 through L4 have been moved towards the image side, while changing the distance therebetween.

[D] At the second intermediate focal length fm2, the first variable lens group 10 and the second variable lens

group 20 are moved towards the image side at the long focal length extremity of the intermediate zooming range Zm; and the first sub-lens group S1 moves to the image-side movement extremity of the guide groove 13, and wherein the first sub-lens group S1 moves toward the second sub-lens group S2 so that the distance therebetween is determined by a shorter distance (second separation space/narrow space) d2.

[E] In a long-focal-length zooming range Zt from the second intermediate focal length fm2 to the long focal length extremity ft, the first sub-lens group S1 and the second sub-lens group S2 maintain the shorter distance d2 therebetween, and the third sub-lens group S3 and the fourth sub-lens group S4 maintain the shorter distance d4 therebetween; and the first variable lens group 10 and the second variable lens group 20 move towards the object side based on the positions thereof which are determined at the second intermediate focal length fm2, after the first through fourth lens groups L1 through L4 have been moved towards the image side, while changing the distance therebetween.

The zoom paths for the first variable lens group 10 and the second variable lens group 20 are simply depicted as straight lines in Figure 6. It should be noted, however,

that the actual zoom paths are not necessarily straight lines.

Focusing is performed by integrally moving, in the optical axis direction, the first sub-lens group S1 and the second sub-lens group S2, i.e., the first variable lens group 10 (first lens group frame 11) regardless of the zooming range.

Similar to the first through fifth embodiments, in the sixth embodiment, the zoom paths are discontinuous at the first intermediate focal length fm1 and the second intermediate focal length fm2; however, a solution for continuously forming a correct image plane exists by appropriately determining the positions of the first sub-lens group S1 (first lens group L1), the second sub-lens group S2 (second lens group L2), the third sub-lens group S3 (third lens group L3), and the fourth sub-lens group S4 (fourth lens group L4), respectively, at the short focal length extremity fw, the first and second intermediate focal lengths fm1, fm2 (discontinuous line), and the long focal length extremity ft. According to such a zoom path, a miniaturized zoom lens system having a high zoom ratio can be obtained.

Figure 7 shows the seventh embodiment of the zoom lens

system with a switching lens group. The zoom lens system includes a positive first variable lens group 10, and a negative second variable lens group 20, in that order from the object side. The first variable lens group 10 includes a positive first lens group L1 (first sub-lens group S1), a negative second lens group L2 (second sub-lens group S2) and a positive third lens group L3 (third sub-lens group S3), in that order from the object side. The second variable lens group 20 includes a negative fourth lens group L4. The first sub-lens group S1 and the third sub-lens group S3 are fixed to a first lens group frame 11. The second sub-lens group S2 is mounted on a movable sub-lens group frame 12. The movable sub-lens group frame 12 is arranged to move in the optical axis direction, by a predetermined distance, along a guide groove 13 which is formed on the first lens group frame 11. The second sub-lens group S2 is selectively moved to either the object-side movement extremity at which the movable sub lens group frame 12 comes into contact with the front end of the guide groove 13, or the image-side movement extremity at which the movable sub-lens group frame 12 comes into contact with the rear end of the guide groove 13. The fourth lens group L4 of the second variable lens group 20 is fixed to a second lens group frame 21. A

diaphragm D is arranged to move together with the first variable lens group 10 (first lens group frame 11).

In the zoom paths according to the seventh embodiment, the first variable lens group 10 (first lens group frame 11), the second variable lens group 20 (second lens group frame 21), and the second sub-lens group S2 move in the following manner:

[A] In a short-focal-length zooming range Zw from the short focal length extremity fw to an intermediate focal length fm, the first sub-lens group S1 and the second sub-lens group S2 maintain a shorter distance therebetween; however, the second sub-lens group S2 and the third sub-lens group S3 maintain a longer distance therebetween; and the first variable lens group 10 (first lens group frame 11) and the second variable lens group 20 (second lens group frame 21) move towards the object side while changing the distance therebetween.

[B] At the intermediate focal length fm, the first variable lens group 10 and the second variable lens group 20 are moved towards the image side at the long focal-length extremity of the short-focal-length zooming range Zw; and the second sub-lens group S2 moves to the image-side movement extremity of the guide groove 13, and wherein the

second sub-lens group S2 moves away from the first sub-lens group S1 and moves toward the third sub-lens group S3.

[C] In a long-focal-length zooming range Zt from the intermediate focal length fm to the long focal length extremity ft, the first sub-lens group S1 and the second sub-lens group S2 maintain the longer distance therebetween, and the second sub-lens group S2 and the third sub-lens group S3 maintain the shorter distance therebetween; and the first variable lens group 10 and the second variable lens group 20 move towards the object side based on the positions thereof which are determined at the intermediate focal length fm, after the first through fourth lens groups L1 through L4 have been moving towards the image side, while changing the distance therebetween.

The zoom paths for the first variable lens group 10 and the second variable lens group 20 are simply depicted as straight lines in Figure 7. It should be noted, however, that the actual zoom paths are not necessarily straight lines.

Focusing is performed by integrally moving, in the optical axis direction, the first sub-lens group S1 through the third sub-lens group S3, i.e., the first variable lens group 10 (first lens group frame 11) regardless of the

zooming range.

Similar to the first through sixth embodiments, in the seventh embodiment, the zoom paths are discontinuous at the intermediate focal length fm; however, a solution for continuously forming a correct image plane exists by appropriately determining the positions of the first sub-lens group S1 (first lens group L1), the second sub-lens group S2 (second lens group L2), the third sub-lens group S3 (third lens group L3), and the fourth lens group L4, respectively, at the short focal length extremity fw, the intermediate focal length fm, (discontinuous line), and the long focal length extremity ft. According to such a zoom path, a miniaturized zoom lens system having a high zoom ratio can be obtained.

As can be understood from the above description, it is practical to apply the above-described zoom lens system having switching lens groups to a photographing lens system of a camera in which the photographing lens system and a finder optical system are independently provided. Moreover, with respect to each of the first through fourth lens groups L1 through L4, stopping positions at which the lens group stops upon zooming are preferably determined in a stepwise manner along a fundamental zoom path, i.e., it

is preferable to provide a plurality of focal-length steps. Figures 8 and 9 show zoom lens systems in which positions for stopping each lens group are determined in a stepwise manner along the fundamental zoom paths. Since these zoom lens systems are the same as that of the first embodiment, identical components are provided with the same designators. The zoom paths are depicted with fundamental dotted lines; and positions at which the first lens group frame 11 and the second lens group frame 21 stop are indicated with black dots along the dotted lines. Further, in Figure 9A, the dots are connected by smooth (continuous) curved lines to form an actual zoom path. The actual mechanical structure thereof allows the first lens group frame 11 and the second lens group frame 21 to be moved along the smooth curved lines (actual zoom path).

In the first through seventh embodiments, each lens group is illustrated as a single lens element; however, a lens group can of course include a plurality of lens elements.

Figures 9B and 9C depict an additional schematic view of the concepts shown in Figs. 8 and 9A. It should be noted in the following explanation that Figures 9B and 9C are schematic in nature (e.g., not to scale and/or not depicting

actual shape) and that one skilled in the art will recognize that the zoom paths are not necessarily straight, and the manner in which the schematics of Figs. 9B and 9C relate to a designed (zooming) cam groove shape (which will differ depending at least on the optical configuration). As shown in Fig. 9B and 9C, if, in order to arrange movement in accordance with Fig. 9A, it is determined that one zoom path will be connected in an uninflected line (i.e., essentially without discontinuity or inflection and without switching), then the cam ring, shape, and orientation of cam groove(s) can be adapted for this purpose. As shown in Fig. 9B, each of the three fundamental zoom paths can include a discontinuity. By smoothly connecting one zoom path, in this case the second zoom path (e.g., depicted in the Figures 9B and 9C by shifting all of the zoom paths in the intermediate-to-telephoto range "up" so that the path of the second lens group is connected), it becomes possible to carry out the movements of the combined groups more simply. In this case, it is decided to use "switching" for the first group and a smooth inflection in the second group. As noted, the stepwise movement/positioning and prohibition of photography in the switching/inflection range also form part of this system.

Although Fig. 9C depicts a shift in which the second zoom path is made essentially connected, the amount of shifting "up" does not need to fully align the curve to be made smoother, but need only take up a portion of the discontinuity (e.g., reducing any inflection to a selected amount, such as an imperceptible amount). In the following description, it is noted that cam groove 44f is essentially without discontinuity or inflection, relating to the second group zoom path in Figs. 9A-9C, and that cam groove 44r has a small inflection, relating to the third group zoom path in Figs. 9A-9C. However, the adaptation depicted in Figs. 9B and 9C can be used for any of the systems depicted in Figs. 1-7 or variations thereof.

It can be decided to use at least one smooth or uninflected line for various reasons, including simplicity of movement, simplicity of manufacturing, or to improve exterior appearance of movement of lens barrels (e.g., to avoid visible discontinuity in the operation of the lens barrels, so that an unsophisticated operator does not become concerned about the proper operation of the camera). In the example given, the movement of the lens barrel supporting the second lens group is essentially continuous, while the switching movement of the first lens group and the inflected

movement of the third lens group cannot be seen from the exterior of the camera.

In each of the above-described embodiments, the first variable lens group 10 in Figures 1, 8, and 9A-9C, the second variable lens group 20 in Figure 2, the second variable lens group 20 in Figure 3, the first variable lens group 10 in Figure 4, the first variable lens group 10 in Figure 5, the first variable lens group 10 in Figure 6, and the first variable lens group 10 in Figure 7 (including the first lens L1 and the third lens L3 as a unit) are each switching lens groups which serve as focusing lens groups in any focal length range.

A preferred embodiment will now be described in which the present invention has been applied to the zoom lens barrel in the examples shown in Figures 1, 8, and 9A-9C, which have a first variable lens group 10 (switching lens group) and a second variable lens group 20.

Figures 10 through 31 show an embodiment of a zoom lens barrel (system). Unlike the zoom lens systems shown in Figures 1, 8 and 9, in which one of the first and second sub-lens groups S1 and S2, which together form a switching lens group 10, is fixed to the first lens group frame 11, the first and second sub-lens groups S1 and S2 in this

embodiment are both movable with respect to the switching lens group frame in the optical axis direction. In this embodiment, a moving path of the switching lens group frame upon zooming and a path of the first sub-lens group S1 and the second sub-lens group S2 within the switching lens group frame can be added to each other to give a composite zoom path, which corresponds to the zoom path shown in Figures 1, 8, and 9A-9C. Upon focusing, the first sub-lens group S1 and the second sub-lens group S2 are integrally moved within the switching lens frame in the optical axis direction. In a photographic operation, the first sub-lens group S1 and the second sub-lens group S2 are placed at a predetermined position, before the release of the shutter is started, as a result of the movement of the switching lens group frame and the movement of the first sub-lens group S1 and the second sub-lens group S2 within the switching lens group frame in accordance with focal length information set by an operator (the photographer) and object distance information detected.

As shown in Figure 10, a stationary barrel 42, which is fixed to a camera body 41, has a female helicoid 43 formed on an inner surface of the stationary barrel 42. A male helicoid 45, which is formed on the rearmost circumference

of a cam ring 44, engages with the female helicoid 43. Arranged outside of the stationary barrel 42 is a pinion 47 which is rotated by a zooming motor 46. Gear teeth (not shown) are formed on the circumference of the cam ring 44 wherein a part of the male helicoid 45 is cut out therefor. The gear teeth, which are formed to have the same oblique direction as the lead of the male helicoid 45, engages with the pinion 47. Accordingly, the cam ring 44 advances or retreats along the optical axis direction when the cam ring 44 is rotated in either direction by the zooming motor 46 due to the engagement of the female helicoid 43 and male helicoid 45. The position of the cam ring 44 resulting from the rotation made by the zooming motor 46 is detected by focal length detecting device 46C, which can include, for example, of a code plate and a brush.

A linear guide ring 48 is supported by the cam ring 44. The guide ring 48 rotates relative to the cam ring 44 and moves together with the cam ring 44 along the optical axis direction (i.e., no relative displacement is allowed in the optical axis direction). The guide ring 48 is supported by a camera body 41 in a manner that enables the guide ring 48 to move only in the optical axis direction. Arranged inside of the cam ring 44 in order from the front

side of the cam ring 44 are a switching lens group frame 50 (first lens group frame) which supports the first variable lens group 10 (i.e., the first sub-lens group S1 and second sub-lens group S2) and a second lens group frame 49 which supports the second variable lens group 20. The switching lens group frame 50 and the second lens group frame 49 are linearly guided along the optical axis direction by the guide ring 48.

Cam grooves 44f and 44r are formed on an inner surface of the cam ring 44. The cam grooves 44f and 44r receive the switching lens group frame 50 and second lens group frame 49, respectively. Figure 11 shows an arrangement of the cam grooves 44f and 44r in a developed view. Three sets of the cam grooves 44f and 44r are formed circumferentially with each groove spaced at equi-angular distances from one another. Radial follower pins 50p and 49p are provided on the switching lens group frame 50 and the second lens group frame 49 to be received in the cam grooves 44f and 44r, respectively.

The cam grooves 44f and 44r include introducing portions 44f-a and 44r-a for the follower pins 50p and 49p, retracted portions 44f-r and 44r-r for the zoom lens system, wide-angle extremity portions 44f-w and 44r-w, and

telephoto extremity portions 44f-t and 44r-t, respectively. A rotational angle θ_1 is defined as the rotational angle from the introducing portions 44f-a and 44r-a to the retracted portions 44f-r and 44r-r, respectively. A rotational angle θ_2 is defined as the rotational angle from the retracted portions 44f-r and 44r-r to the wide-angle extremity portions 44f-w and 44r-w, respectively. A rotational angle θ_3 is defined as the rotational angle from the wide-angle extremity portions 44f-w and 44r-w to the telephoto extremity portions 44f-t and 44r-t, respectively. A rotational angle θ_4, defined as the rotational angle beyond the telephoto extremity portions 44f-t and 44r-t, which serves as a rotational angle for assembly use. Each of the cam grooves 44r for the second lens group frame 49 has an intermediate discontinuous position fm that corresponds to the zoom path of the second variable lens group 20 as described in the embodiments in Figures 1, 8 and 9.

In contrast, no discontinuous position appears to exist in the cam grooves 44f for the first variable lens group 10 between the wide-angle extremity portion 44f-w and the telephoto extremity portion 44f-t since the change in shape (profile) of each cam groove 44f is smooth in this area. This is because, in this embodiment, the switching

lens group frame 50 and the sub-lens group S2 are moved in such a manner that the positions of the sub-lens group S2 are not discontinuous in the short-focal-length zooming range Zw and in the long-focal-length zooming range Zt, the two ranges extending on both sides of intermediate focal length fm in Figure 1. A connection line CC is schematically shown in Figure 1. The connection line CC connects the zoom path of the short-focal-length zooming range Zw to zoom path of the long-focal-length zooming range Zt, the two ranges extending on both sides of the intermediate focal length fm. The cam groove 44f is shaped to correspond to the zoom path connected by the connection line CC. As the follower pin 50p moves along a section corresponding to the connection line CC, the sub-lens group S1 moves from the object-side movement extremity to the image-side movement extremity. It is necessary to control the zoom lens barrel so that the section of the cam groove 44f corresponding to the line CC is not used as an actual zooming range in a photographic operation (i.e., the cam ring 44 is not stopped). Alternatively, the cam grove 44f can include the discontinuous position similar to that of the cam groove 44r.

In the above-described zoom lens barrel, the cam ring

44 advances or retreats along the optical axis while rotating as the pinion 47 is rotated via the zooming motor 46 in either direction, which causes the switching lens group frame 50 (i.e., the first variable lens group 10) and the second lens group frame 49 (i.e., the second variable lens group 20), which are guided in the optical axis direction within the cam ring 44, to move in the optical axis direction along a predetermined path defined by the cam grooves 44f and 44r.

Novel features of the present embodiment reside in a support structure by which the first sub-lens group S1 and the second sub-lens group S2 are supported in the switching lens group frame 50 and the driving structure thereof. A particular example of an arrangement within the switching lens group frame 50 will now be described by reference to Figures 12 through 31.

As shown in Figures 15 and 16, a front shutter retaining ring 51, a rear shutter retaining ring 52, a first sub-lens group frame 53, a second sub-lens group frame 54, an actuator ring 55, and a gear holding ring 56 are arranged within the switching lens group frame 50. The front shutter retaining ring 51, the rear shutter retaining ring 52, and the gear holding ring 56 form a portion of the switching lens

group frame 50. The first sub-lens group S1 is fixed to the first sub-lens group frame 53, and the second sub-lens group S2 is fixed to the second sub-lens group frame 54. The first sub-lens group frame 53, the second sub-lens group frame 54, and the actuator ring 55 are movably fitted in a central opening 51p (see Figure 12) of the front shutter retaining ring 51. These movable members, i.e., the first sub-lens group frame 53, the second sub-lens group frame 54, and the actuator ring 55, enable the first sub-lens group S1 and the second sub-lens group S2 to be at a mutually close position, or be at a mutually distant position, with respect to the optical axis direction, and also enable the first sub-lens group S1 and the second sub-lens group S2 to perform focusing.

The actuator ring 55 is rotatably supported between the front and rear shutter retaining rings 51 and 52 with the rearmost portion of the actuator ring 55 being restricted by a receiving surface 52a (Figures 13, 15, and 16) of the rear shutter retaining ring 52. The actuator ring 55 is a driving member that enables the first sub-lens group S1 and the second sub-lens group S2 to become mutually close or mutually distant from each other, and enables the first and the second sub-lens groups S1 and S2 to perform

focusing via the rotation thereof. The gear holding ring 56 is fixed to the front end of the front shutter retaining ring 51, and a lens shutter mechanism 57 and a diaphragm mechanism 58 are supported by the rear shutter retaining ring 52 (Figures 12, 15, and 16).

The first sub-lens group frame 53 has a cylindrical shape and has two linear guide ribs 53a on its periphery at the opposite sides thereof at an equi-angular interval of 180 degrees. A guide bore 53b is formed in the guide rib 53a. A guide rod 59 is loosely inserted (or moveably fitted) in the guide bore 53b. The rear end of the guide rod 59 is fixed in a fixing bore 56q formed at the rearmost portion of the gear holding ring 56 while the front end of the guide rod 59 is fixed to the front surface of the gear holding ring 56 by a bracket 60 and a screw 61. A coil spring 62 is placed over each of the guide rod 59 between the bracket 60 and the guide rib 53a so that the coil spring 62 biases the first sub-lens group frame 53 toward the second sub-lens group frame 54. A U-shaped recess 56r is provided on the gear holding ring 56 so as to receive the guide rod 59 and the spring 62 (Figures 25 through 27). The recess 56r communicatively connects with the central opening 51p of the front shutter retaining ring 51. The first sub-lens group

frame 53 can be connected to the front shutter retaining ring 51 by engaging the guide ribs 53a with the guide rods 59 of the front shutter retaining ring 51 at two positions, wherein the guide ribs 53a are provided on the first sub-lens group frame 53 at 180° intervals about the optical axis.

As shown in Figures 17A, 18A, 19A and 20A, the first sub-lens group frame 53 is provided with four shift leading surfaces (shift cam surfaces) 53c that are formed circumferentially at equi-angular intervals on the end-face of the first sub-lens group frame 53. Annular light-blocking support ribs 53d (see Figure 14) are provided radially outside of the shift leading surfaces 53c over the open ends of the shift leading surfaces 53c. Figure 23 shows an enlarged expanded view of one of the shift leading surfaces 53c which is formed essentially as a straight slope having an inclination angle α with respect to a circumferential edge of the first sub-lens group 53 (i.e., with respect to a plane normal to the optical axis), and is provided with a pair of follower engaging recesses 53e and 53f on either end of the shift leading surface 53c. Each of the engaging recesses 53e and 53f is formed as a shallow V-shaped recess. The follower engaging recess 53e defines

a mutually distant position on the wide-angle side and the follower engaging recess 53f defines a mutually close position on the telephoto side, of the first sub-lens group frame 53 and the second sub-lens group frame 54 (i.e., the first sub-lens group S1 and second sub-lens group S2).

As shown in Figures 17A, 18A, 19A and 20A, the second sub-lens group frame 54 is provided on its periphery with four follower projections 54a, each corresponding to each of the four shift leading surfaces 53c of the first sub-lens group frame 53. An inclined surface 54b is provided so as to correspond to the shift leading surface 53c of the first sub-lens group frame 53, and the follower projection 54a is provided on the end of the inclined surface 54b which is the closest to the shift leading surface 53c. The tip of the follower projection 54a has a substantially semi-circular shape which is symmetrical with respect to the longitudinal axis thereof, so that the shapes of the engaging recesses 53e and 53f correspond to the tip shape of the projection 54a. Annular light-blocking support ribs 54c are radially provided on the second sub-lens group frame 54 inside the projections 54a and the inclined surfaces 54b. The shift leading surfaces 53c formed on the first sub-lens group frame 53 and the follower projections 54a formed on the

second sub-lens group frame 54 together form a shift cam mechanism (of a lens group shift mechanism) that enables the lens-group frames 53 and 54 either be at a mutually close position, or be at a mutually distant position. As described above, the four shift leading surfaces 53c of the first sub-lens group frame 53 and the four projections 54a of the second sub-lens group frame 54 are spaced at equi-angular intervals. Accordingly, each of the surfaces can engage with its respective projection at 180° intervals of a relative rotation. Given that N is the number of the shift leading surfaces 53c or the follower projections 54a (four, in this embodiment) and that M is the number of the guide ribs 53a of the first sub-lens group frame 53 or the number of the guide rods 59 of the front shutter retaining ring 51 (two, in this embodiment), the relationship between M and N is that M is a multiple of N, or in other words, N is a divisor of M. This relationship makes it possible to select an assembly position from among different assembly positions, so that for example, an assembly position that provides optimum optical performance can be achieved.

Furthermore, a pair of linear guide projections 54d are formed on the second sub-lens group frame 54 on the outer surface thereof. The guide projections 54d are formed at

the same circumferential positions as two of the four follower projections 54a that are positioned on the periphery of the second sub-lens group frame 54 at the opposite sides thereof at an equi-angular interval of 180 degrees. Each of the guide projections 54d is formed at a position which is rearward with respect to the follower projection 54a in the optical axis direction. Also formed on the second sub-lens group frame 54 on the outer surface thereof are three lugs 54e, which are spaced at equi-angular intervals, and are positioned rearward with respect to the guide projection 54d in the optical axis direction. As best shown in Figure 24, each lug 54e has a pair of contact surfaces N1 and N2 that are spaced apart from each other in a circumferential direction. Each lug 54e also has a smooth circular shaped end surface N3 that is symmetrical with respect to the central axis of the lug 54e extending in the middle of the contact surfaces N1 and N2.

As shown in Figure 24, a pair of rotation preventing surfaces 51a and 51b are formed on the front shutter retaining ring 51 on the inner surface thereof, in order to define the range of rotation of the second sub-lens group frame 54 relative to the non-rotating front shutter retaining ring 51, with respect to the guide projection 54d

of the second sub-lens group frame 54. The rotation preventing surfaces 51a and 51b come into contact with contact surfaces M1 and M2 of the guide projection 54d, respectively, when the second sub-lens group frame 54 is rotated in either direction, thereby defining the rotational movement extremities of the second sub-lens group frame 54. A wide-angle linear guide slot 51d is defined between the rotation preventing surface 51a and a guide surface 51c which comes into contact with the contact surface M2 of the guide projection 54d. A telephoto linear guide slot 51f is defined between the rotation preventing surface 51b and a guide surface 51e which comes into contact with the contact surface M1 of the guide projection 54d. Thus, the width of both of the wide-angle linear guide slot 51d and the telephoto linear guide slot 51f in the circumferential direction corresponds to that of the linear guide projection 54d in the same direction. Accordingly, the guide projection 54d snugly fit in the guide slots 51d and 51f so as to movable therein.

The clearance between the wide-angle linear guide slot 51d or the telephoto linear guide slot 51f and the guide projection 54d is determined smaller (stricter) than the clearance between the guide bore 53b of the first sub-lens

group frame 53 and the guide rod 59. The linear guide projections 54d are provided on the periphery of the second sub-lens group frame 54 on opposite sides thereof at an equi-angular interval of 180 degrees. A pair of the wide-angle and telephoto linear guide slots 51d and 51f are provided on the front shutter retaining ring 51 so that two linear guide projections 54d can be selectively received in the wide-angle and telephoto linear guide slots 51d and 51f with respect to the rotational positions thereof (i.e., at an angular interval of 180 degrees).

The actuator ring 55 has, on the front end surface thereof, three control recesses 55a that each correspond to each of the lugs 54e of the second sub-lens group frame 54 (see Figure 22). Each of the control recesses 55a has a shape that is symmetrical with respect to the central axis extending parallel to the optical axis and includes a pair of effective surfaces 55b and 55c that respectively come into contact with contact surfaces N1 and N2. The lugs 54e of the second sub-lens group frame 54 and the control recesses 55a constitute a focusing cam mechanism of a focusing mechanism. The control recess 55a also includes a pair of focus leading surfaces 55d and 55e (focus cam surfaces) on the telephoto side and on the wide-angle side,

respectively. The focus leading surfaces 55d and 55e each come into contact with the circular end surface N3 of the lug 54e. The telephoto-side focus leading surface 55d and the wide-angle-side focus leading surface 55e are provided between the effective surfaces 55b and 55c in the form of an end-faced cam having an open front end. The slopes of the leading surfaces 55d and 55e have opposite directions with respect to the circumferential direction thereof, but have the same absolute value, i.e., the slopes both incline forwards in the optical axis direction. Annular light-blocking support ribs 55f (see Figure 13) are provided radially outside, and over the front portion, of the control recess 55a of the actuator ring 55. The focus leading surfaces 55d and 55e, together with the lug 54e provided on the second sub-lens group frame 54, form a focus cam mechanism. As described above, the three lugs 54e of the second sub-lens group frame 54 and the three control recesses 55a of the actuator ring 55 are spaced at equi-angular intervals. In the illustrated embodiment, each of the lugs can engage with a respective recess at 120° angular intervals.

The aforementioned coil springs 62, which bias the first sub-lens group frame 53 rearward, so that the shift

leading surfaces 53c contact the follower projections 54a, and the lugs 54e of the second sub-lens group frame 54 contact the telephoto side or wide-angle side focus leading surfaces 55d or 55e of the actuator ring 55. As described above, the rear end surface of the actuator ring 55 abuts the receiving surface 52a of the rear shutter retaining ring 52. Accordingly, the first sub-lens group frame 53, the second sub-lens group frame 54, the actuator ring 55, and the rear shutter retaining ring 52 (receiving surface 52a) can be held in contact by the sole force exerted by the coil springs 62. As can be clearly seen from Figures 15 and 16, when the first sub-lens group frame 53, the second sub-lens group frame 54, the actuator ring 55, and the rear shutter retaining ring 52 are in engagement with each other, the front end of the second sub-lens group frame 54 is positioned inside the first sub-lens group frame 53, and the actuator ring 55 is situated on the periphery of the second sub-lens group frame 54.

Figure 21(A through H) shows the manner in which the first sub-lens group frame 53 and the second sub-lens group frame 54 (i.e., the first sub-lens group S1 and the second sub-lens group S2) are moved via the effective surfaces 55b and 55c between a mutually close position on the telephoto

side and a mutually distant position on the wide-angle side. Note that, solid line arrows represent the rotational direction of the actuator ring 55, in Figure 21.

The arrangement shown in Figure 21(A) is the mutually distant position on the wide-angle side, in which the effective surface 55b of the actuator ring 55 abuts the lug 54e, and the linear guide projection 54d of the second sub-lens group frame 54 is disengaged from the wide-angle linear guide slot 51d. As the actuator ring 55 rotates in a clockwise direction (i.e., moves to the right in Figure 21), the effective surface 55b biases the contact surface N1 of the lug 54e to rotate the second sub-lens group frame 54 clockwise (to the right in Figure 21) until the linear guide projection 54d abuts the rotation preventing surface 51b (Figures 21(A) through 21(C)). During the rotation of the actuator ring 55 and the second sub-lens group frame 54, the first sub-lens group frame 53 (i.e., the first sub-lens group S1) follows the shift leading surface 53c, and the follower projection 54a of the second sub-lens group frame 54 so that the first sub-lens group frame 53 linearly moves closer to the second sub-lens group frame 54 (i.e., the second sub-lens group S1) (Figure 21(B)). Ultimately, the follower projection 54a engages with the follower engaging

recess 53f and rearward movement of the first sub-lens group frame 53 with respect to the second sub-lens group frame 54 in the optical axis direction is stopped (Figure 21(C)). Since the follower projections 54a and the follower engaging recesses 53f are spaced at equi-angular intervals therebetween, eccentricity between the first sub-lens group frame 53 and the second sub-lens group frame 54 is prevented, with all of the projections and the recesses in engagement. This completes the switching from the mutually distant position on the wide-angle side to the mutually close position on the telephoto side, resulting in the first sub-lens group S1 being in a mutually close position with respect to the second sub-lens group S2(i.e., mutually close extremity). Note that the actuator ring 55 cannot rotate further in this direction.

Upon completion of switching to the mutually close position on the telephoto side, the rotation of the actuator ring 55 is reversed. The lug 54e (i.e., the second sub-lens group frame 54) moves rearward following the telephoto side focus leading surface 55d until the linear guide projection 54d engages with the telephoto linear guide slot 51f. This allows the linear projection 54d to move only in the optical axis direction (Figure 21(D)). Focusing is carried out on

the telephoto side from the intermediate focal length to the long focal length extremity, with the second sub-lens group frame 54 and the first sub-lens group 53 being moved integrally at the mutually close position via the telephoto side-focus leading surface 55d.

Once the actuator ring 55 is rotated until the effective surface 55c abuts the contact surface N2 of the lug 54e, the linear guide projection 54d of the second sub-lens group frame 54 disengages from the telephoto linear guide slot 51f (Figure 21(E)).

At this point, the rotation of the actuator ring 55 has been reversed (upon or after completion of the switching to the mutually close position on the telephoto side). As the actuator ring 55 rotates counterclockwise (i.e., moves to the left in Figure 21), the effective surface 55c biases the contact surface N2 of the lug 54e to rotate the second sub-lens group frame 54 leftward until the contact surface M1 of the linear guide projection 54d abuts the rotation preventing surface 51a (Figures 21(F) and 21(G)). During the rotation of the actuator ring 55 and the second sub-lens group frame 54, the first sub-lens group frame 53 follows the shift leading surface 53c and the follower projection 54a of the second sub-lens group frame 54 so that the first

sub-lens group frame 53 linearly moves away from the second sub-lens group frame 54. Ultimately, the follower projection 54a engages with the follower engaging recess 53e and forward movement of the first sub-lens group frame 53 with respect to the second sub-lens group frame 54 in the optical axis direction is stopped (Figure 21(G)). Since the follower projections 54a and the follower engaging recesses 53f are spaced at equi-angular intervals therebetween, eccentricity between the first sub-lens group frame 53 and the second sub-lens group frame 54 is prevented, with all of the projections and the recesses in engagement. This completes the switching from the mutually close position on the telephoto side to the mutually distant position on the wide-angle side, resulting in the first sub-lens group S1 being in a mutually distant position with respect to the second sub-lens group S2 (i.e., mutually distant extremity). Note that the actuator ring 55 cannot rotate further in this direction.

Upon completion of switching to the mutually distant position on the wide-angle side, the rotation of the actuator ring 55 is reversed. The lug 54e (i.e., the second sub-lens group frame 54) moves rearward following the wide-angle side focus leading surface 55e until the linear

guide projection 54d engages with the wide-angle linear guide slot 51d. This allows the linear projection 54d to move only along the direction of the optical axis (Figures 21(G) and 21(H)). Focusing is carried out on the wide-angle side from the intermediate focal length to the short focal length extremity, with the second sub-lens group frame 54 and the first sub-lens group frame 53 being moved integrally at the mutually distant extremity via the wide-angle side focus leading surface 55e.

Once the actuator ring 55 is rotated until the effective surface 55c abuts the contact surface N1 of the lug 54e, the linear guide projection 54d of the second sub-lens group frame 54 disengages from the wide-angle linear guide slot 51d, and the positions of the first sub-lens group frame 53 and the second sub-lens group frame 54 return back to the position shown at Figure 21(A).

Figure 22 shows the principle of how the focusing is carried out via the telephoto side-focus leading surface 55d and the wide-angle side-focus leading surface 55e. As the actuator ring 55 is rotated in a telephoto side focusing range pt (from an infinite photographic distance ∞ to a minimum photographic distance (object at a minimum distance) n), with the circular end surface N3 of the lug

54e in contact with the telephoto side focus leading surface 55d, the second sub-lens group frame 54 (whose rotation is confined by the linear guide projection 54d which is in engagement with the telephoto linear guide slot 51f) and the first sub-lens group frame 53 (i.e., the first sub-lens group S1 and the second sub-lens group S2) integrally moves forwardly or rearwardly along the optical axis to thereby carry out focusing. Similarly, as the actuator ring 55 is rotated in a wide-angle side focusing range pw (from an infinite photographic distance ∞ to a minimum photographic distance (object at a minimum distance) n), with the circular end surface N3 of the lug 54e in contact with the wide-angle side focus leading surface 55e, the second sub-lens group frame 54 (whose rotation is confined by the linear guide projection 54d which is in engagement with the wide-angle linear guide slot 51d) and the first sub-lens group frame 53 (i.e., the first sub-lens group S1 and the second sub-lens group S2) integrally moves forwardly or rearwardly along the optical axis to provide focusing.

In particular, focusing on the telephoto side and focusing on the wide-angle side are achieved by controlling the number of pulses counted by a encoder 64p (see Figure 30) provided in a driving system which drives the actuator

ring with respect to a reference position at which the linear guide projection 54d of the second sub-lens group frame 54 comes into contact with the rotation preventing surface 51a or 51b (i.e., the position where the rotation of the actuator ring 55 is reversed). For example, the number of pulses of the driving system required to move the focusing lens groups (i.e., the sub-lens groups S1 and S2) from a reference position to a position corresponding to a minimum photographic distance n, to a position corresponding to an infinite photographic distance ∞, and to a position corresponding to an intermediate photographic distance can be predetermined by taking the leading angles for the focus leading surfaces 55d and 55e into consideration. Accordingly, focusing can be properly carried out in accordance with the object distance information by managing the number of the pulses of the encoder.

Also, in the illustrated embodiment, the slopes of the telephoto side focus leading surface 55d and the wide-angle side focus leading surface 55e of the actuator ring 55 have opposite directions with respect to the circumferential direction thereof, but have the same absolute value, i.e., the slopes both incline forwards in the optical axis direction, and the lug 54e is shaped to be symmetrical with

respect to the central axis extending in the middle of the contact surfaces N1 and N2 which are circumferentially spaced apart from each other. Accordingly, focusing can be carried out on the telephoto side in the same manner as on the wide-angle side. This facilitates focusing control.

Figures 17A and 17B show an arrangement of the first sub-lens group frame 53, the second sub-lens group frame 54, the actuator ring 55, and the front shutter retaining ring 51 when the first sub-lens group frame 53 (i.e., the first sub-lens group S1) and the second sub-lens group frame 54 (i.e., the second sub-lens group S2) are in the mutually distant position at the wide-angle side, and are in a position so as to focus on an object at infinity. Figures 18A and 18B show an arrangement of the first sub-lens group frame 53, the second sub-lens group frame 54, the actuator ring 55, and the front shutter retaining ring 51 when the first sub-lens group frame 53 and the second sub-lens group frame 54 are in the mutually distant position on the wide-angle side, and are in a position so as to focus on an object at a minimum distance. Figures 19A and 19B show an arrangement of the first sub-lens group frame 53, the second sub-lens group frame 54, the actuator ring 55, and the front shutter retaining ring 51 when the first sub-lens group

frame 53 and the second sub-lens group frame 54 are in the mutually close position on the telephoto side, and are in a position so as to focus on an object at infinity. Figures 20A and 20B show an arrangement of the first sub-lens group frame 53, the second sub-lens group frame 54, the actuator ring 55, and the front shutter retaining ring 51 when the first sub-lens group frame 53 and the second sub-lens group frame 54 are in the mutually close position on the telephoto side, and are in a position so as to focus on an object at a minimum distance. The first sub-lens group frame 53, the second sub-lens group frame 54, the actuator ring 55, and the front shutter retaining ring 51 are shown separated in the optical axis direction in Figures 17A, 18A, 19A and 20A, and are shown in operation in Figures 17B, 18B, 19B and 20B.

Gear teeth 55g are formed over a circumference on the rear-end periphery of the actuator ring 55. As shown in Figures 12, 29 and 30, the gear teeth 55g engage with a series of reduction gears 63a. The series of reduction gears 63a are rotated in either direction by a bi-directional motor 64 which also includes the encoder 64p. The series of reduction gears 63a are held between the front shutter retaining ring 51 and the gear holding ring 56, and the bi-directional motor 64 is held by the rear shutter

retaining ring 52. The gear teeth 55g of the actuator ring 55, which are formed over the entire periphery thereof, makes it easy for the three control recesses 55a to engage with the three lugs 54e of the second sub-lens group frame 54 at different relative rotational positions that are separated by 120°.

The lens shutter mechanism 57 and the diaphragm mechanism 58 are mounted on the rear shutter retaining ring 52. In particular, as shown in Figures 12, 15 and 16, the lens shutter mechanism 57 includes a shutter sector support plate 57a, three shutter sectors 57b, and a shutter drive ring 57c for opening and closing the shutter sectors 57b. The diaphragm mechanism 58 includes a diaphragm sector support plate 58a, three diaphragm sectors 58b, and a diaphragm drive ring 58c for opening and closing the diaphragm sectors 58b. These components are retained in the rear shutter retaining ring 52 by a sector holding ring 57d. The shutter sector 57b and the diaphragm sector 58b include a pair of dowels. One of the dowels is rotatably supported by the support plates 57a and 58a and the other is rotatably fitted to the drive rings 57c and 58c. The lens shutter mechanism 57 opens and closes an aperture formed by the shutter sectors 57b as the shutter drive ring 57c is

rotated. The diaphragm mechanism 58 varies the size of an aperture formed by the diaphragm sectors 58b as the diaphragm drive ring 58c is rotated.

Sector gear teeth 57g are formed on a part of the periphery of the shutter drive ring 57c and engage with a series of reduction gears 63b that are sequentially arranged from a shutter drive motor 57m (see Figure 12). When the shutter drive motor 57m is rotated in either direction, the aperture, which has been closed by the shutter sectors 57b, is momentarily opened and is then closed again. In the zoom lens barrel of the illustrated embodiment, the shutter sectors 57b serve both as a variable diaphragm to provide an aperture of an arbitrary size, and as a shutter. The shutter sectors 57b are electrically controlled so that the size of the aperture of the shutter sectors 57b (aperture value) and the length of time during which the aperture is left opened (i.e., shutter speed) can be varied depending on the exposure, upon the release of the shutter. Furthermore, the diaphragm drive ring 58c includes a lug 58g on the periphery thereof. The lug 58g engages with a diaphragm-controlling cam slot 48s formed on an inner surface of the linear guide ring 48 (see Figure 10). Upon zooming, the linear guide ring 48 and the rear shutter

retaining ring 52 (i.e., the diaphragm drive ring 58c) moves relative to each another in the optical axis direction. This causes the lug 58g to follow the diaphragm-controlling cam slot 48s so as to move in the circumferential direction. This in turn causes the diaphragm drive ring 58c to rotate and, as a result, the size of the aperture formed by the diaphragm sectors 58b is varied. The diaphragm sector 58b is provided to restrict the maximum value of the aperture diameter especially in the wide-angle side photographing range, and the degree of opening of the aperture is mechanically varied in accordance with the amount of extension of the zoom lens barrel.

As shown in Figure 31, the zooming motor 46 for the cam ring 44, the bi-directional motor 64 for the actuator ring 55, and the shutter drive motor 57m for the lens shutter mechanism 57 are controlled by a control circuit (control device) 66. Focal length information 67, which is set by the user (photographer) via a zoom switch or the like, detected object distance information 68, object brightness information 69, information on rotational positions of the cam ring 44, which is provided by a focal length detecting device 46C, and information on rotational positions of the motor 64, which is provided by the encoder 64p, are inputted

to the control circuit 66. The zooming motor 46, the bi-directional motor 64 and the shutter drive motor 57m are controlled according to the inputted information so that exposure is carried out under proper exposure conditions in accordance with the predetermined focal lengths. While the shutter sectors 57b serve both as a shutter and as a variable diaphragm, and the diaphragm sectors 58b restrict the aperture diameter upon photographing on the wide-angle side in this embodiment, the diaphragm sectors 58b can be provided as a motor-driven variable diaphragm mechanism.

In the illustrated embodiment, the focal length detecting device 46C (i.e., a rotational position detecting device for the cam ring 44) detects rotational positions of the cam groove 44f which correspond to the connection line CC (see Figure 1), such that the control circuit 66 does not allow the cam ring 44 to stop in this section. If the zoom lens system is provided as a step zoom lens, positions at which the cam ring 44 stops are controlled in a stepwise manner. As described above, while the operations, corresponding to the preset focal length, distance to the object, and the brightness of the object, of the zoom lens barrel (i.e., photographing optical system) having the above-described switching lens group can be completed

immediately before the shutter is released, the focal length set by an operator can be confirmed via a separate finder optical system (not shown) that is provided separate from the photographing optical system.

In the zoom lens barrel using the lens barrel for the switching lens groups, positions at which the switching lens group frame 50, the first sub-lens group frame 53, and the second sub-lens group frame 54 stop upon a photographic operation can be practically determined in a stepwise manner along the zoom path.

Note that, while the lens support/drive structure has been described with regard to the first variable lens group 10 shown in Figures 1, 8 and 9, the mechanical construction of the above-described lens barrel is also applicable to the second variable lens group 20 in Figure 2, the second variable lens group 20 in Figure 3, the first variable lens group 10 in Figure 4, the first variable lens group 10 in Figure 5, the first variable lens group 10 in Figure 6, and the first variable lens group 10 in Figure 7 (the first lens L1 is integrally formed with the third lens L3).

In the above-described lens barrel, the gear holding ring 56 and the rear shutter retaining ring 52 are secured to the front and rear ends of the front shutter retaining

ring 51, respectively. The front shutter retaining ring 51, the rear shutter retaining ring 52 and the gear holding ring 56 together form a single cylindrical unit, i.e., a support barrel SP (see Figure 14). Arranged inside the support barrel SP from the front side (object side) of the optical axis are the first sub-lens group frame (lens frame) 53, the second sub-lens group frame 54 and the actuator ring 55. As the actuator ring 55 is rotated, the first sub-lens group frame 53 and the second sub-lens group frame 54 move to the above-described mutually distant position on the wide-angle side and to the mutually close position on the telephoto side. The sub-lens group frames 53 and 54 are also moved in the optical axis direction together in the mutually distant position and mutually close position, in accordance with the rotation of the actuator ring 55. The assembly/disassembly structure for the sub-lens group frame in the support barrel SP is characteristic of the present invention.

When the support barrel SP is assembled, the gear teeth 55g of the actuator ring 55 are held between the front shutter retaining ring 51 and the rear shutter retaining ring 52, preventing the movement of the actuator ring 55 in the optical axis direction while allowing the actuator ring 55 to rotate (see Figures 15 and 16). The receiving surface

52a is formed on the rear shutter retaining ring 52 and defines the rearmost position of the actuator ring 55.

The first sub-lens group frame 53 and the second sub-lens group frame 54 can be pulled out of and put back into the assembled support barrel SP through the front opening of the support barrel SP (i.e., the central opening 51p indicated in Figure 12). Upon assembly, the second sub-lens group frame 54 is first assembled into the support barrel SP.

The second sub-lens group frame 54 can be moved rearward until the lug 54e abuts the focus leading surface 55d or 55e as it is pushed rearward in the optical axis direction with the two guide projections 54d, formed on the outer surface of the second sub-lens group frame 54, being aligned with the wide-angle linear guide slots 51d or telephoto linear guide slots 51f, which are formed on the inner surface of the front shutter retaining ring 51. Once the lug 54e abuts the focus leading surface 55d or 55e, further insertion of the second sub-lens group frame 54 is blocked by the actuator ring 55, which is kept from moving rearward by the receiving surface 52a. As described above, when the guide projections 54d are inserted into the wide-angle linear guide slots 51d or the telephoto linear guide slots 51f, the second sub-lens group frame 54 can be

aligned at two diametrically opposite positions separated by 180° . In doing so, the relative rotational position of the actuator ring 55 with respect to the second sub-lens group frame 54 is correctly determined as shown in Figure 21.

Following the insertion of the second sub-lens group frame 54, the first sub-lens group frame 53 is attached to the support barrel SP. The first sub-lens group frame 53 can be attached by simply aligning the guide ribs 53a, which are arranged on the outside of the first sub-lens group frame 53 at two radially opposite positions, with the U-shaped recesses 56r on the gear holding ring 56. The first sub-lens group frame 53 in such an assembly state is pushed rearward by a predetermined distance in the optical axis direction until the four shift leading surfaces 53c come into contact with the four follower projections 54a of the second sub-lens group frame 54. As described above, the first sub-lens group frame 53 is assembled into the support barrel SP at two diametrically opposite positions separated by 180° .

Following the insertion of the first sub-lens group frame 53, the bracket 60 is attached to the front surface of the gear holding ring 56, which forms a part of the support barrel SP. The pair of guide rods 59 are provided on the

bracket 60 at positions corresponding to the positions of the two guide ribs 53a on the front sub-lens group frame 53. Though the bracket 60 and the guide rods 59 are shown separate in Figure 13, the guide rods 59 are secured to the bracket 60 as shown in Figure 14 before the bracket 60 is attached to the gear holding ring 56. The bracket 60 is then secured to the front surface of the support barrel SP via the pair of screws 61. Each guide rod 59 is placed through the guide bore 53b formed on each of the guide ribs 53a. The end portions of the guide rods 59 then engage with the fixing bores 56q formed through a rib-like bottom (rod receiving portion) 56y, which is formed on the inner surface of the gear holding ring 56. The first sub-lens group frame 53 is thus guided in the optical axis direction within the support barrel SP due to the engagement of the guide rods 59 with the guide bores 53b. In addition, the bracket 60 covers the front surface of the guide rib 53a (Figures 15 and 16) and thus prevents the first sub-lens group frame 53 from coming off frontwards. With the first sub-lens group frame 53 being prevented from coming off, the second sub-lens group frame 54 is also prevented from coming off.

The pair of coil springs (biasing springs) 62 are placed over the guide rods 59 between the guide rib 53a of

the first sub-lens group frame 53 and the bracket 60 before the bracket 60 is secured to the support barrel SP. As shown in Figures 15 and 16, a spring-receiving portion 53r is formed around the periphery of the guide bore 53b on the guide rib 53a of the first sub-lens group frame 53 to receive one end of the spring 62. The guide bore 53b extends through the bottom of the spring-receiving portion 53r.

The coil spring 62, placed between the bracket 60 and the guide rib 53a, biases the first sub-lens group frame 53 toward the second sub-lens group frame 54. As a result, the shift leading surface 53c of the first sub-lens group frame 53, which is provided in the form of an end-faced cam, is constantly biased so as to be in contact with the follower projection 54a of the second sub-lens group frame 54, and the lug 54e of the second sub-lens group frame 54 is constantly biased so as to be in contact with the wide-angle side or telephoto side focus leading surface 55d or 55e of the actuator ring 55. The biasing force of the coil spring 62 is ultimately born by the receiving surface 52a of the shutter retaining ring 52 (which forms part of the support barrel SP) via the actuator ring 55. In other words, the first sub-lens group frame 53 and the second sub-lens group frame 54, and the second sub-lens group frame 54 and the

actuator ring 55 are arranged with respect to each other so that an end-faced cam portion and a follower portion engage with each other to transmit the force in the optical axis direction. Since rearward movement of the rearmost actuator ring 55 is prevented by the receiving surface 52a, the bias of the coil spring 62 can only hold the first sub-lens group frame 53 and the second sub-lens group frame 54 in place in the optical axis direction. It is not necessary to mount the springs separately since the coil springs 62 come into effect the instant the bracket 60 is secured. This facilitates mounting of the components.

When this assembly is disassembled, the screws 61 are unscrewed and the bracket 60 is pulled out of the support barrel SP from the front end thereof. Once the bracket 60 has been pulled out along with the guide rods 59, the guiding function of the guide rods 59 to guide the first sub-lens group frame 53 in the optical axis direction is lost and the first sub-lens group frame 53 and the second sub-lens group frame 54 can now be pulled out in front of the support barrel SP in that order. This process of pulling out the components is the reverse of the above-described assembly process.

As described above, the bracket 60 having guide rods

59 for guiding the first sub-lens group frame 53 is mounted on the support barrel SP in order to guide the first sub-lens group frame 53 in the lens barrel. Thus, the first sub-lens group frame 53 and the second sub-lens group frame 54 are prevented from coming off the front of the support barrel SP. In other words, the number of steps required in assembling the lens barrel can be reduced since the device for preventing the switching lens group coming off and the device for guiding the first sub-lens group frame 53 are attached at a time. Disassembly of the lens barrel is also facilitated since the first sub-lens group frame 53 and the second sub-lens group frame 54 can be pulled out in front of the support barrel SP by simply removing the bracket 60.

As can be understood from the above discussion, the present invention facilitates assembly/disassembly of the lens barrels having a lens group guided in the optical axis direction of the lens group.

However, the present invention is not limited to this embodiment. For example, while the present invention is particularly suitable for use with lens barrels having a switching lens group such as the sub-lens groups S1 and S2, the present invention is also effective when applied to lens barrels in which a support barrel retains a single lens group.

In the case where the single lens group forms a focusing lens group that is moved in the optical axis direction relative to the support barrel, the above-described features of the present invention (specifically, fixing bores 56q, guide rods 59, bracket 60 and screws 61) may be incorporated for enabling the support barrel to support the focusing lens group while preventing it from coming off. In such cases, components other than the end-faced cam as described in the embodiment, such as solenoids or feed screws, may be employed as an actuator device for moving the focusing lens group in the optical axis direction.

Furthermore, obvious changes may be made in the specific embodiments of the present invention described herein, such modifications being within the spirit and scope of the invention claimed. It is indicated that all matter contained herein is illustrative and does not limit the scope of the present invention.